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This publication is directed toward planning and organizing the collection and disposal of refuse in developing nations. The report describes various methods of collection such as bulk bins and household refuse, types of equipment used and the costs for each type. Other pertinent information on life cycle costing, maintenance needs, contract collection, transfer stations, incineration and composting is also presented.

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REFUSE MANAGEMENT IN DEVELOPING NATIONS

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PREFACE

The United States Environmental Protection Agency (EPA) has received numerous requests from developing nations for information and assistance on management of refuse collection and disposal. In response to this need, the Office of International Activities requested that the Deputy Assistant Administrator of the Office of Solid Waste prepare a report that could be used by developing nations to help them understand and implement an improved refuse management system.

Refuse management is difficult in any nation since it requires a combination of land, labor, capital and management on a continuing basis. Often national and local governments are not fully aware of the many options in equipment and facility selection that can reduce long-range costs and labor/management problems and assure the success of the refuse system. Thus, this report is directed at decision makers in developing nations, to help them understand the problems and ramifications of their decisions on the success or failure of the refuse collection and disposal system.

This project is part of a broad program of technical assistance being carried out by EPA, Office of Solid Waste, to help improve the collection and disposal of refuse in the United States as well as developing nations. This report was written by John W. Thompson, Local Program Manager, and is based on discussions and visits to developing nations.

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REFUSE MANAGEMENT IN DEVELOPING NATIONS

Objectives of a National Program

Refuse management is the orderly process of picking up the discards of a community from many locations and hauling them off to processing or disposal sites. The objectives of the collection disposal cycle should be to: (1) protect the health and aesthetic conditions of the community by collecting and disposing of refuse in a sanitary fashion; (2) provide a desired level of service in terms of frequency and point of collection on a continuing basis; (3) achieve these objectives with the highest productivity and at the least cost to the government.

By definition, increased productivity means more tons collected per hour with the same or less labor. Generally, this will result in the lowest cost. Many think the only means to increase productivity is for laborers to work harder. In general, this is not true. Higher productivity can be achieved in almost any refuse system through the correct policy decisions and improved management techniques in operations. Primary management decisions affecting productivity are: (1) system policies on method of collection and funding; (2) equipment selection; (3) vehicle routing--scheduling; (4) distance and time to the disposal site; (5) management of the operation.

The objective of a national refuse program is to promote the protection of health and the environment by the following actions:

- Provide technical and financial assistance to provincial and local government agencies for the development of refuse management plans that will promote improved refuse management techniques, more effective organizational arrangements, new and improved methods of collection, processing, or recovery of refuse and the environmentally safe disposal of refuse.

- Provide grants (funds) for the design, construction, acquisition, and maintenance of refuse systems, equipment, and facilities.

- Prohibit future open dumping of refuse and require the conversion of existing open dumps to sanitary landfills, which do not pose a danger to the environment or to health.

- Regulate the transportation and disposal of hazardous or industrial wastes that have adverse effects on health and the environment.

- Provide for the promulgation of rules, regulations, and guidelines for solid waste collection, transportation, separation, recovery, and disposal practices, and systems.

- Promote national research and development programs for improved solid waste management and resource conservation techniques, more effective organizational arrangements, and for new and improved methods of collection, processing, and environmentally safe disposal of refuse and non-recoverable residues.

- Promote the demonstration, construction, and application of refuse or solid waste management practices that preserve and enhance the quality of the environment.

- Establish cooperative efforts among national, provincial, and local government agencies.

- Institute permit or licensing systems for private haulers of industrial, commercial or hazardous wastes to ensure that the refuse is disposed in a sanitary landfill and is not dumped in a promiscuous manner.

Definitions of Terms Used Throughout This Report

1. The term "refuse or solid waste" means any garbage, refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility, and other discharged materials, including solid, liquid, semi-solid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities.

2. The term "refuse management" means the systematic administration of activities to provide for the collection, separation, storage, transportation, transfer, processing, recovery, treatment and disposal of refuse.

3. The term "refuse facility" includes: (a) any collection, processing or resource recovery system or component thereof; (b) any system, program, or facility for resource conservation; (c) any facility for the treatment of refuse, including hazardous wastes, whether such facility is associated with facilities generating such waste or otherwise.

4. The term "refuse planning" includes refuse management, comprehensive planning, implementation planning or management, as well as guidelines, rules, regulations, and agreements which further the objectives of refuse management.

5. "Hazardous waste" means any refuse or combination of refuse or solid wastes, which, because of the quantity, concentration, physical, chemical, or infectious character, may: cause or significantly contribute to an increase in serious irreversible, or incapacitating reversible, illness; or, pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

COLLECTION METHODS AND FUNDING POLICIES

The initial decisions on the type of collection-disposal practices should be predicated on the long-range funding commitment by the local government to operate the system. In many instances, local governments have acquired vast amounts of new equipment, but did not make provision for the follow-up on funding to adequately maintain and operate the collection-disposal system. It is not unreasonable to assume that annual operating costs will be about equal to the initial capital investment made in the equipment. Thus, a city purchasing two million dollars worth of new trucks must also plan on spending two million dollars annually over the next five years for labor, repair, maintenance, insurance, overhead and administrative costs. In a typical collection system in the United States, costs for various functions are: labor, 60%; maintenance and truck operation, 20%; depreciation, 10% and administration, 10%. (In developing nations, labor costs would be proportionately less, due to lower wages, and vehicle operating costs higher due to the greater cost for imported equipment and parts.) In the United States (U.S.), collection costs generally represent 85% and land disposal 15% of total collection-disposal costs.

The larger the annual operating budget, the higher the level of service that can be provided to the public. Cities with large budgets often have twice-per-week household collection from the backyard, whereas cities with smaller budgets have once-per-week refuse collection at the street.

An often overlooked fact is that 15% of the refuse in the U.S. is not collected on a regular basis. This generally applies to rural areas where the homeowner must transport the waste to a centralized location for bulk bin collection. Often, the bulk bins are 1-8 km from the resident's home.

Very few governments in developing nations are sufficiently affluent to afford a high level of refuse collection service. Therefore, bulk bin collection appears to be the least costly, most productive means of collection, and ordinary sanitary landfilling the least costly means of disposal. Average U.S. collection-disposal costs is presented below to help decision makers understand the economics of various collection-disposal options and their costs (Table 1).

Type of Refuse and Generation Rates

In general, the more affluent a community, the more waste is generated. While the U.S. generation rate by citizens is 1.25 kg per person per day, a typical generation rate in a developing nation is about 0.5 kg per person per day. Another big variation is in the composition of the waste. In the U.S., about 75% of the waste stream is combustible materials, whereas in developing nations, about 75% of the waste stream is non-combustible vegetable matter. The density of uncompacted organic refuse is 180 kg per m^3 or about 3 times greater than inorganic refuse. Therefore, the type, size, and kind of equipment utilized for collection and disposal of organic wastes should take this into consideration. For example, compacting inorganic waste to 650 kg per cubic meter is difficult, whereas compacting waste containing 75% organic materials is much easier. The waste composition will influence the size and type of truck (chassis, frame, axles and body) needed to do the job.

TABLE 1

Average U.S. Costs per Tonne for Various Refuse Options, 1981

(Costs include Interest and Depreciation on Capital)

Activity	Dollars per tonne	Ratio to landfill costs
Landfilling	6.00	1.0
Collection (individual houses)	46.00	7.7
Collection Bulk Bins		
(a) Rear Loaders $6m^3$	34.85	5.8
(b) Front Loaders $6m^3$	18.70	3.1
(c) Tilt Frames $26m^3$	8.60	1.4
Transfer Station to Landfill (24 Km-1 way distance)	9.20	1.5
Incinerators (80% combustibles)	43.15	7.2
Incinerators-Supplemental Fuel (80% non-combustibles)	69.00	11.5

In developing nations, the large amount of organic material and its corresponding density have not always been considered in the selection of equipment. For example, three men can usually lift a barrel of inorganic material into a packer truck, whereas a barrel full of organic matter would be too heavy. Organic waste, being more dense than inorganic waste, can be easily compacted to a high density, and blowing or loose refuse is not a serious problem. Thus, the weight and density of vegetable wastes is a reason for the utilization of bulk mechanical collection of refuse in many developing countries.

Door-to-Door Collection

Door-to-door collection is the highest level of service a community can provide its citizens. It is also the most expensive: about $60 per household per year, or $43 per tonne (Mg). It assumes: every citizen or household to have a container, or to purchase plastic refuse bags; that trucks can maneuver down the streets; that a dependable, highly organized labor force is available for collecting the refuse. About 75% of the households in the U.S. have their refuse collected once a week at the curb. For those citizens in the U.S., as well as in developing nations who desire a higher level of service such as more frequent collection or backyard carryout service, it is customary to contract with private haulers of refuse and to pay a higher price directly to the hauler for this higher level of service. This same principle can be applied to collection from affluent citizens in developing nations.

Bulk Bin Collection

Bulk bin collection is the lowest level of service and the least costly method of refuse collection a government can provide the citizens. Bulk bins or containers ranging in size from $6m^3$ to $26m^3$ are common throughout the world. About 15% of the U.S. residential refuse and all of the U.S. commercial and industrial waste is collected in this manner. The bulk bins are placed at strategic or convenient locations and citizens transport their waste to the centralized bin locations.

Bulk bins can and should work well in developing nations for the following reasons:

a. It is the most cost effective means in terms of labor and equipment necessary to do the job. Costs per ton, depending on size of containers, are only one-fourth to one-half of the costs of door to door collection.

b. Management is simplified. Fewer trucks and workers are needed, thereby reducing management problems.

c. Maneuvering trucks down narrow streets is avoided.

d. Collection can be done at night and, since the time lost negotiating day-time traffic may decrease productivity by 50%, costs can be lowered. All large U.S. cities do night-time collection in central areas of the cities.

e. Injuries are reduced, since laborers do not lift the refuse.

f. If night collection is instituted, truck maintenance can be done during the day.

g. Most cities in developing nations now have centralized points for locating bulk bins such as markets, dust bins, and night soil stations; these points are known and used by the citizens.

h. Based on the U.S. experience, 97% of the citizens can and will transport their refuse to a central collection point (bulk bin) and there is no reason to think citizens in developing nations will not follow the same trend.

i. Weight of refuse (organics) is heavier in developing nations and thus mechanical means for loading vehicles is warranted.

Common objections to bulk bins are:

a. Some citizens want pickup at their houses. Affluent citizens should either pay a private hauler or have their household help carry the refuse to a centralized location.

b. That there will be an excess of laborers. (Excess laborers should be utilized with wheelbarrows, shovels, and brooms in cleaning up the streets, ditches, gutters, and around the centralized bin locations and depositing the refuse into the bulk bins for collection.)

c. Drivers must be paid a night wage differential. This is a valid argument for bulk bin collection at night, but the increased productivity will more than make up the difference. The higher night wage differential can also help the city attract and hold qualified, trained drivers.

d. When trucks are left alone in bulk bin collection, they are subject to robberies and equipment is subject to vandalism. (Conventional dumping of bulk bins does not require drivers to leave the truck, therefore, robbery is difficult.) Trucks can be equipped with floodlights on top of the cab and the driver and helper can carry mace or other gas repellants to discourage vandals.

Selection and Placement of Bulk Bins

It is not unusual for a city to operate two types of bulk bin systems. Small bins of $6m^3$ to $9m^3$ are placed in strategic locations in residential areas, perhaps one per city block. Larger $26m^3$ to $45m^3$ bins are placed at market areas, public housing developments, apartments, government buildings, and other areas where there is a high population concentration. Although the body of the truck is quite different for collecting each type of bin, selection of the truck chassis, motor, etc. may be the same. About 80% of all truck repair costs are for the chassis and only 20% for the packer (body).

Cities which can standardize the truck frame, engine, and transmission, will have lower maintenance costs, since the mechanics need only to learn to repair one kind of truck and the city can reduce the number of spare parts in its inventory.

When utilizing bulk bins for refuse, it is important to keep the sides as low as possible so citizens can throw their refuse over the side. If the sides are high, wood or concrete platforms must be constructed so citizens can walk up a ramp to throw their refuse into the bin. In general, a 1.2m high bin is the recommended height. Cities need not reduce the volume of the bin to have low sides, but merely change the length or width of the bulk bin. Although the initial capital cost for bins is high, they usually have a 10-year life and can be easily fabricated by local companies. Hinged tops or sliding sides are not worth the extra investment. Their purpose is to reduce blowing paper, insects, rodents, and odor, however, in practice, it has been found that only one lid per 100 containers is ever entirely closed, both in developing nations and in the U.S. Also, problems with lid maintenance and filling the bulk bins full are eliminated if lids or sliding sides are not used.

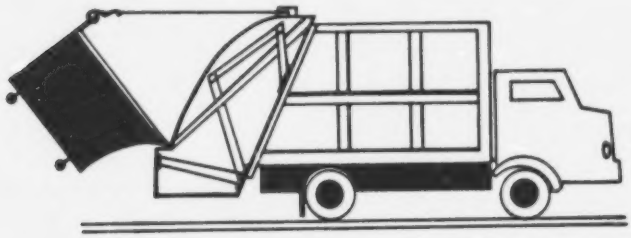
There are four primary types of bulk bin collection equipment on the market: rear-loading, front-loading, and tilt frame compactors (Figure 1), and side-loading compactors (not illustrated).

a. Rear-loading compactors are the least efficient method and costly, for several reasons. Trucks must back up to the container and often laborers must push, pull, or position the container before hooking onto it. Even bulk bins with wheels are difficult to position, since they get caught in mud, on stones, or in depressions. Also, maintenance of the wheels is difficult and expensive. Dumping the containers with a cable and winch is slow. Because of the time and extra labor needed for emptying the bins, the cost of this system is estimated at $43 a tonne in the U.S. This assumes two trips a day to the landfill, loose inorganic waste at 64 kg pounds per m^3 and $60 for the vehicle. Naturally, hydraulic dumping systems, compaction cycle time, traffic, and distance between bins and to the landfill will influence all the cost examples.

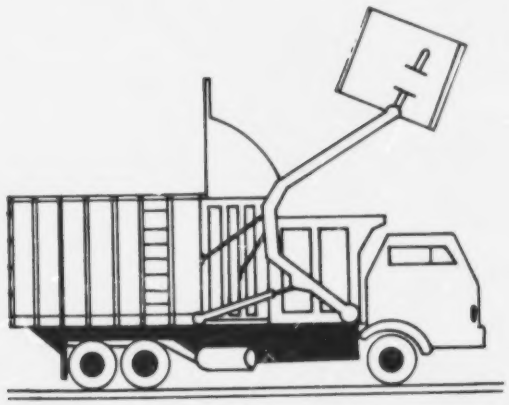
b. Front-loading compactor trucks are the most customary type of commercial or bulk bin collection vehicle used in the United States. In practice, it can be operated with only the driver. Truck costs range from $60,000 to $90,000 depending on the size of truck and packer. Based on two trips a day to a disposal site, these vehicles generally move 18 tonnes a day at $21.50 per tonne. Bin sizes are generally $3m^3$ to $6m^3$. Larger trucks must have tandem rear axles which have higher operating costs than do smaller, single rear axle trucks.

c. Tilt-frame, or roll-off noncompaction trucks are generally used to move large amounts of heavier density wastes such as the organic wastes prevalent in developing countries. Container (bin) size and truck size can be varied to accommodate weight and density of refuse. A $26m^3$ bin hauling loose refuse generally does not need a tandem axle

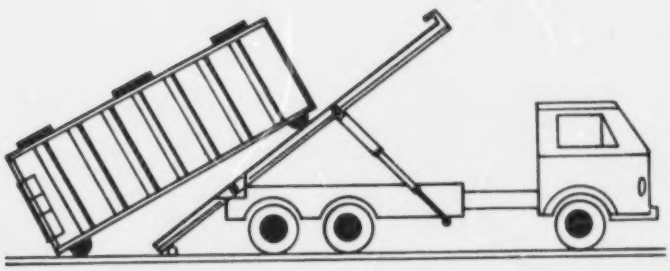
FIGURE 1
Three Types of Bulk Container Trucks



A. Rear-Loading Compactor—Average Capacity 9 Tonnes Per Day



b. Front-Loading Compactor—Average Capacity 17 Tonnes Per Day



c. Tilt-Frame or Roll-Off Container Truck—Average Capacity 34 Tonnes Per Day

truck. Costs for this system are estimated at $10.75 per tonne for about four trips daily to the disposal site. Nets or tarpaulins should be provided for covering the load if it is overly full, windy conditions exist, or the refuse is high in inorganics, such as paper. However, most vegetable refuse found in developing countries is sufficiently moist so that nets are not necessary.

d. Side-loading compactor trucks are a fourth means of dumping bulk bins. Laterally moving arms extend 30 inches out from the truck to grab the bin and hoist it up high enough to dump its contents. Most of the systems employing these arms use $1m^3$ round plastic or steel containers, but the arms are adaptable to rectangular $6m^3$ bins. The advantages of this type of mechanical loading are that the truck can collect bins in streets as narrow as 3.65m, the truck never needs to back up, and the compaction is all done from front to rear, eliminating the need and cost for multi-push and packing blades. Also, the empty vehicle weight is less than conventional rear packers, allowing a greater payload. Typical cost estimates are $21.50 per tonne for moving 18 tonnes per day.

   Conventional side-loading packers for using bulk bins have been on the market for years, but, like rear packers, additional labor is required to position the bins. Consequently, these are not as cost effective as the newer type side loaders.

ESTIMATING EQUIPMENT AND VEHICLE REQUIREMENTS

The first and most important determination administrators must make is the volume of waste generated in the city on a daily basis and the weight of the refuse. If we assure a generation rate in developing nations of 0.5kg per person per day and 200kg per cubic meter, then a city of 1 million inhabitants needs 1,250m^3 of bin capacity daily. Twenty percent additional should be added for seasonal variations and contingencies. Thus, 1,500m^3 in bins are needed for each million persons. If we assume the city plans to empty each bin every two days, and operate the system six days a week using the 20% seasonal variation to take care of the seventh nonwork day, then 3,000m^3 in bulk bins are needed per million residents.

A more difficult problem is to determine the mix of 26m^3 bins and 6m^3 bins. Since the larger bins are the least costly to collect, planners should first attempt to locate sites where the large bins can be placed and serviced. Population density and truck services should also be considered. If a 6m^3 bin were placed at the corner of a city block to service more than 2,000 persons, it would have to be serviced daily. In general, for cost effectiveness and service, it works best to locate as many 26m^3 bins at strategic locations as possible. If we assume 60 sites where large 26m^3 bins were located, then the need for 1,190m^3 of bin capacity are satisfied. The remaining 1,100m^3 needed for collection every two days would require 250 of the 6m^3 bins. Planning for the location, size and frequency of collection is never perfect, and adjustments will be needed after the collection system is started. Rather than change the size or location of bulk containers, the easiest adjustment is to change the frequency of service.

For example, a 26m^3 bin at a market might need servicing daily, whereas a 26m^3 bin at an apartment might only need to be collected twice per week. The same principle applies to 6m^3 bins. Radio equipped trucks and a supervisor who reports when bins are full will pay for itself quickly in mileage costs saved servicing partially filled bins.

Determining the number of trucks needed is more difficult than determining the number and size of bins. Time and motion studies are needed to determine: minutes needed to service each container; time between containers; time to disposal site; time needed at disposal site; time to return; and time to and from the garage; allowances for breakdowns and other variables. This phase of a refuse system design should be done by a multi-disciplinary task force of engineers, planners, and transportation experts who, collectively will not overlook the fact that time delays at a landfill or transfer station, adverse weather conditions, or accidents on main roads, can and will impact seriously on the number of trucks needed. Collection at night can help reduce the error in the number of trucks needed because of reduced traffic congestion and delays occuring at night.

There is no rule of thumb or standard for determining the number of trucks needed for a city. Each municipality must, by necessity, calculate the time needed for each vehicle to service a given number of bulk bins and then add at least 20% to the fleet of trucks for downtime, repairs, and contingencies.

If we assume the tilt frame trucks make four trips a day to the disposal site and there are 30 of the $26m^3$ sites to be serviced nightly, then 8 trucks are needed. If each of the front loading compactor trucks can make three round trips to the disposal site with 5 tonne loads, then each truck can service 12 of the $6m^3$ bins nightly. Since 125 of the $6m^3$ bins must be serviced nightly, 13 trucks are needed. This does not allow for breakdowns and contingencies.

In summary, for each one million persons, the city would need 60-$26m^3$ bins and 8 trucks, plus 250 of the $6m^3$ bins and 13 trucks. To accommodate breakdowns, repairs, and maintenance, every municipality must have spare vehicles. Some cities with excellent maintenance programs are able to operate with only 10% spare vehicles, but the normal amount is 20-30% spare vehicles. Some small municipalities share spare vehicles on a rental basis to the owning municipality.

All cities must make extensive plans for phasing in new collection practices over a 1-3 year period, since training of drivers, mechanics, and supervisors, and routing of vehicles, takes time and diligent work. It is imperative that a city do one area at a time and do a thorough, complete job before moving to another area. The introduction of crews and trucks over an entire city can lead to chaos and a breakdown of what might otherwise be a good system if initially confined to one area.

LANDFILLS AND TRANSFER STATIONS

The least costly means of refuse disposal is landfilling (Table 1). The second least costly means of disposal is to process the refuse through a transfer station onto transfer trailors, generally hauling 13.5 tonnes each to the landfill. The general rule of thumb of when it is advisable to initiate the use of transfer stations for hauling refuse to remote landfills is: when the round trip time to the landfill requires more than one hour driving time, or when the haul distance is more than 25km one way.

Assuming a city has a landfill in the south and east quadrant, often the most cost effective means of collecting and disposing of refuse is to direct haul from these quadrants to the landfill and erect transfer stations for the north and west quadrants.

Many cities today have one or two primary roads bisecting the main city and these roads can provide fast access to a new landfill 15-25km from the center city if the landfill is located adjacent to the main highway and if refuse is hauled at night when traffic congestion is limited.

Sanitary landfilling is the least costly operation in refuse collection and disposal and should be utilized when and where practical. In the U.S., the average cost in 1978 was $6 per tonne. In general, as tons placed per day increase, costs for landfilling decrease. Taking refuse through a transfer station adds an estimated $9.20 per tonne to refuse costs. This assumes an average 54km round trip haul. Hauling costs are estimated at 10 cents per tonne per km for truck and driver.

New York City, disposing 12,000 tonnes a day in one landfill had an average cost of $2.72 per tonne in 1977, and Dallas, Texas, operating 7 landfills in 1978, had average costs of less than $3.30 per tonne. Over 80% of all landfill costs are for equipment and the labor to operate this equipment.

There are five primary principles to operating a sanitary landfill around which policy makers should center their decisions: (a) protection of the ground water for the present and forseeable future, especially if it will contaminate a public water supply; (b) discouragement of scavengers, usually through the use of fences; (c) control of insects and rodents; (d) prevention of open burning; (e) periodic, and preferrably frequent, compacting and covering of the waste with dirt. This last principle is the most expensive part of landfill operation.

Although bulldozers have been the favored piece of landfill equipment over the years, use of landfill compactors is rapidly gaining acceptance. The big advantage of compactors is that the refuse is more densely packed, therefore more refuse can be put in the same amount of space at no additional cost. Hauling of cover materials should be done with a scraper which moves 15-30m^3 of dirt.

PROCESSING; RECOVERY OF WASTE MATERIALS

Incineration

Only 4% of the U.S. waste stream is burned in incinerators. To date incinerators have not proven economically feasible due to high capital and operating costs. They are also a major source of air pollution and only about seven incinerators have been able to meet the U.S. air pollution standards. In the 1950's, over 300 municipalities operated incinerators, and by 1978 this had decreased to about 42 cities.

The feasibility of operating incinerators in the U.S. is much more favorable than in developing nations because the refuse is 80% inorganics, such as paper and plastics, which burn without supplemental fuel. In order to burn organic refuse of the type found in most developing rations, supplemental fuel must be used. This is both expensive and directly opposed to energy conservation. In addition to the technology needed to build the plants, skilled trained workers are needed to operate the plant on a 24-hour basis for economy of scale.

Typical personnel needed to operate an incinerator are certified welders, electrical and mechanical engineers, tool and die mechanics, and firebrick masons. Explosions do occur from paint, propane cans, and other volatile materials, putting the incinerator out of use, often for long periods of time. While they are effective at controlling air pollution, electrostatic precipitators require considerable amounts of electricity and periodic maintenance. Electrical brownouts or blackouts of a power supply for even a short period of time can result in long and costly delays in restarting the operation. In all cases, there is an incinerator residue of 10-35% by weight, depending on the completeness of the burn and amount of glass, metal, and other non-combustibles present which must be transported to the landfill. The decision to install incinerators in developing countries before an adequate refuse collection disposal system is instituted cannot be considered a prudent, rational decision.

Composting

Composting of organic wastes is a viable solid waste disposal alternative. However, composting is much more expensive than landfilling and has several disadvantages. The separation of the organic from inorganic wastes with a high degree of reliability is a problem. Pieces of glass in compost are not wanted by farmers since it cuts their feet and the feet of their animals. Aerobic digestion of the organic matter must occur before the compost is trucked to the farm and this requires some technical ability for controlling the time, temperature, air, and turning of the organic matter before it becomes compost. A major problem is trucking the compost to farms and spreading it. Trucking is expensive, and farmers don't want the compost during either the growing or rainy season. Most farms do not have equipment to spread the compost and the city might have to purchase a compost spreader or pay the farmer to spread the compost. Finally, compost is not a fertilizer. Over the years, urban dwellers in all nations have held the mistaken idea that compost is a substitute for organic fertilizer. Compost is

a soil conditioner, especially good for loosening up clay-type soils. The fertilizer value for increasing crop yield, especially nitrogen, is less than 0.2%. Thus, one ton of compost has a fertilizer value equal to a 2.5kg bag of urea (nitrogen) fertilizer. Experienced farmers will always select fertilizer over compost. In summary, the best use of compost is to spread it on undeveloped land before the land is brought into production.

OPERATIONAL MANAGEMENT

Assuming that several policy decisions have been made on funding, type of service, and equipment needed to do the job, operational management decisions must be made and implemented that will result in a viable refuse collection-disposal system.

Operational management of any refuse system in any city or nation is difficult. Most municipal administrators have the ability to manage white collar workers and their related functions in an office situation. When this same expertise is applied to the management of blue collar workers, a fleet of trucks and a big repair-maintenance facility, something goes wrong. Often, municipal administrators cannot communicate with the blue collar workers, or cannot identify with the basic problems and needs of the workers to keep the system functioning in an efficient manner. In one instance, maintenance of 50 trucks was in chaotic condition because the city's purchasing department held up the paperwork for the purchase of vehicle parts for two months, even though the refuse budget adequately provided for parts acquisition. Labor unrest existed in another city because some drivers worked only 3 hours a day while others worked 6 hours daily. Administrators and planners had not balanced the workload equally among the crews. This should be done on an annual basis and is always supported by labor unions.

Many management studies in recent years have pointed out that wages are not the highest priority issue in developing and maintaining a contented labor force. More important factors are working conditions, good equipment, a fair equitable workload, a grievance procedure, and support of management in their work.

Based on the U.S. experience, the management skills and chain of command that will work best in any municipal refuse collection and disposal system is similar to the military chain of command. The Administrator (battalion major) passes orders to his department heads for collection, disposal, and maintenance (lieutenants). The department heads pass orders to supervisors (first sergeants), on to foremen (staff sergeants), to drivers or mechanics (corporals), who direct laborers (privates). The key to drawing this parallel between Army organization and municipal waste management is the supervisor or first sergeant. In the Army, as well as in refuse collection systems, supervisors or first sergeants must have the ability to communicate between the blue collar workers and managers (officers).

Based on a large number of observations, retired military personnel have been very successful when placed in corresponding positions in refuse management. Often, supervisors or foremen from large construction companies provide another source of trained personnel who have the ability to communicate between blue collar workers and management.

The three primary problems in refuse management which lead to a breakdown of the system are (1) vehicle maintenance, (2) span of control over vehicles and crews, and (3) "permissiveness" in management. Overcoming these problems requires diligent management effort.

Vehicle maintenance is the number-one management problem contributing to missed collections and a breakdown of the refuse collection-disposal system. New York City, with 1,700 refuse trucks generally has 600 down for repair daily. No other vehicle takes the abuse of a refuse truck. It must make hundreds of starts and stops a day in congested traffic, often over poor roads, and then negotiate a landfill with a full load. Although driver abuse is a contributing factor to vehicle breakdowns, most vehicle malfunctions are attributable to improper truck specifications. For these reasons, it is almost impossible to over-spec a refuse truck. Frames should be extra heavy duty, axles should be over-specified by 30-35% to take the wear and tear of a landfill. Engines, transmissions, drive shaft and rear end should be the best available. No one has ever complained that a refuse truck was too strong for the job.

While many cities base their purchases on low bid, the trend is toward life cycle costing. Under this method, truck purchases are based on what the total lifetime cost of the vehicle will be over 5 years, not the initial pur chase price (Table 2). Almost all refuse trucks are depreciated over 5 years.

It is much more important to develop cost data on the truck chassis over a five-year period than on the body or packer mechanism. About 80 percent of truck total maintenance costs are for the chassis and only 20% for the body. Often, bodies in good condition can be removed from old chassis and placed on new trucks for several additional years of life.

Well managed maintenance garages are generally divided into three units: (1) normal or periodic maintenance for oil and lubrication, (2) small repairs such as brakes, fuel, electrical, tires, and (3) major maintenance for the drive train. There have been two trends in recent years for major maintenance. First, complete dealer or truck manufacturer maintenance of the drive train and, second, the use of modular or replacement engines rather than rebuilding engines in the maintenance shop. If a chassis manufacturer must also prepare a bid for drive train maintenance over a five-year period, it will force life-cycle costing on the decision makers and the initial purchase of the truck chassis will be more favorably spec'd for the job. Performance bonding should accompany the drive train maintenance contract.

Poor maintenance of refuse trucks often occurs when the work must be performed in garages which service highway, police, and other municipal vehicles. Most mechanics don't want to work on big, old, smelly, dirty refuse trucks and thus these vehicles are serviced last. Therefore, a separate garage for refuse vehicles' repair and maintenance is recommended.

Selection of mechanics and training is difficult. In any nation there is a shortage of heavy equipment mechanics. In general, these workers require higher pay if a city is to retain competent, qualified truck mechanics. Many municipal garages servicing refuse trucks often employ the wrong type of mechanics or do not provide them with the proper equipment. A study in a major U.S. city of the maintenance requirements over 30 days of 200 refuse trucks indicated 117 needed electrical repairs, 90 brake service, 89 body work, and 61 fuel repairs. Only 48 trucks needed engine work. Thus, this garage needed more mechanics who knew and understood electrical problems and brakes than they did engine mechanics.

TABLE 2

EXAMPLE OF LIFE-CYCLE COSTS

Year	1	2	3	4	5
Capital Investment and Depreciation:					
Trade-in value (% of delivery price)	75%	55%	40%	30%	25%
Investment, start	70,000	52,500	38,500	28,000	21,000
Year-end value	52,500	38,500	28,000	21,000	17,500
Yearly capital cost	17,500	14,000	10,500	7,000	3,500
Debt Service and Insurance:					
Average yearly investment	61,250	45,500	33,250	24,500	19,250
Yearly debt cost @ 12%	7,350	5,460	3,990	3,940	2,310
Operation and Maintenance:					
Yearly estimated cost	4,000	6,000	8,000	12,000	16,000
Downtime:					
Availability factor	95%	94%	91%	88%	85%
Hours not available	60	120	180	240	300
Cost @ $13/hr for reserve vehicle	780	1,560	2,340	3,120	3,900
Obsolescence:					
Productivity factor	98%	96%	94%	92%	90%
Extra hours required to match production of new model	40	80	120	160	200
Cost @ $13/hr	520	1,040	1,560	2,080	2,600
Total Annual Cost	$30,150	$28,060	$26,390	$27,140	$28,310
Cumulative Vehicle Cost	$30,150	$58,210	$84,600	$111,740	$140,050

Training of mechanics is generally best accomplished by sending the men off to school rather than trying to train them on the job. In addition, aptitude for the type of training offered is very important. A man who has an interest in brakes or transmissions may not have the same inclination to learn electrical repairs. Tire changers might not have a desire to learn hydraulic cylinder repair. An electrical system repair mechanic might best be recruited from an electronic school. A good brake mechanic might be obtained from a farm implement dealer. If the mechanics, even after specialized training, are not capable of doing the job, they should be put to work on something else and the training of replacement mechanics started over again. In the U.S., it is not unusual to employ one good mechanic and helper for every 5 trucks. While this ratio may not be possible in developing nations, one quality mechanic can often do the work of several uninterested, poorly trained or inept mechanics. The role of the foreman and supervisor of the maintenance garage is to continually circulate through the shop, monitoring the mechanics and the work being performed.

Periodic maintenance is a necessity. Often, the excuse is used that there is no time available. If this is a problem, schedule oil changes and grease jobs on weekends or when the vehicle returns from collection, even though overtime must be paid to mechanics. Tires and batteries should be checked daily and replaced if they show any signs of malfunctioning during operation. It is false economy to utilize tires and batteries on vehicles until they break down. The lost time of drivers and workers, as well as the expense of on-route repair or towing, is higher in the long run than discarding tires and batteries before they are worn out.

For some refuse collection systems, it has worked well to schedule periodic and small maintenance repair jobs at night, if collection is made during the day, or during the day if the trucks are operated at night. Standardization of truck chassis types, body engines, transmissions, etc., will facilitate a higher level of performance by mechanics since they only need to learn to repair one type of truck. It also allows the maintenance garage to carry a minimum number of parts. All garages should carry a large number of the common parts, and inventory control of these parts is very important. An adequate replacement supply of belts, radiators, fuel injectors, clutches, generators, starters, etc. will, in the long run, make it possible to keep the fleet operating. The worst practice appears to be overstocking of infrequently used parts or carrying an inventory of parts for obsolete or salvaged vehicles.

A service contract with the seller of truck chassis for repair of the drive train components has several advantages for local municipal governments. The need for highly skilled mechanics necessary to repair or overhaul transmissions and engines is avoided. Often, the city wage scale is not sufficient to attract these specialized mechanics for servicing this equipment. Some dealer contracts guarantee the minimum number of trucks that will be operational each day or provide for backup trucks when an excessive number are in the shop for major repairs. In general, the number of vehicles down for repair in a well managed maintenance facility is 10% of the fleet. In poorly managed maintenance facilities, 25-35% down for repairs is not uncommon. In general, each lost truck hour costs the city $13 for not having the use of the truck.

Everyone subscribes to the ideal of "periodic maintenance", but in reality that objective is seldom achieved. Too often, the words "we don't have time" or "every truck has to go out today" is the excuse used for not performing periodic maintenance. This is false economy and will quickly lead to serious and costly breakdowns. Clogged oil, air, and fuel filters on diesel trucks can ruin engines quickly, causing onroute breakdowns and expensive repairs. A leaking hydraulic cylinder can quickly lead to a scored cylinder and the need for replacement at a cost of several thousand dollars, all because a few dollars worth of gaskets or packing wasn't installed at the first sign of deterioration.

It is very easy for the casual, uninformed observer to determine the quality of a refuse maintenance garage. Is the garage clean and neat? Are tires and tools put away? Is the floor covered with oil and grease? Are tires, batteries, and parts lying all over the place, or are they neatly stored? Is the garage large and well-lighted or small and dingy? Does the outside yard look like a truck salvage yard or a new truck dealer's parking lot? The answer to these questions will almost always determine the quality of the service of the maintenance garage.

Span of control over vehicles, drivers, and crews is the second largest contributing factor to poor refuse management. Depending on the size of the city, a large number of trucks and workers leave a central garage each morning with a $70,000 piece of equipment to do a job and report back to the garage 8 hours later. During this period of time, drivers and crews are often out-of-touch with any sort of management. They have no supervision to keep them working and will tend to featherbed. Often, they are confronted with unusual situations or problems. The truck breaks down, a traffic jam or detour ruins their work schedule and productivity. Often, a man is injured. The crew or driver may not know the route if they are substituting for the regular crew; overlap of routes, half-filled trucks and missed collections result.

Two methods are generally helpful in overcoming the problems associated with span of control. The use of radio-equipped trucks and foremen in pickup trucks driving the area and providing supervision generally work best. If a driver can communicate his problem to a central office, and if the supervisor can shuffle trucks or crews around, the seriousness of productivity losses from onroute problems can be minimized. In cities utilizing bulk bins for the collection of refuse, the supervisor can radio decisions about which containers are full and need tipping, thus increasing productivity and reducing costs. Foremen and supervisors should have the ability to reroute trucks to save time and be able to place containers so they are in the most advantageous position for refuse collection. Other duties of foremen are to switch and interchange crew members who work well together and train new drivers on routes. In practice, about one foreman is needed for each 5-7 routes. Radio-equipped trucks can and will increase productivity, thereby lowering costs and recovering the initial investment in a short period of time. They are especially helpful if the city is divided into areas for collection and all trucks and crews must stay in the area until the entire job is completed.

Permissive management of labor is the third factor contributing to poor refuse collection and disposal. Collection of refuse is not a choice vocation even for blue collar workers. Refuse collection is dirty, smelly, heavy,

boring, and a physically exhausting occupation with little chance of advance ment. For these reasons, the drivers and workers attracted into the occupation are not of the highest caliber. In the U.S., as well as other nations, many of the employees are functional illiterates. However, this does not prevent these individuals from being excellent sanitation workers providing they are trained and given incentives such as pay, vacations, and the opportunity to go home early when the job is done. In practice, low I.Q. drivers may be more desirable because they concentrate on one thing--driving--while high I.Q. drivers often have their minds on other things.

In the U.S., as well as developing nations, poor refuse management can generally be attributed to permissive management. Absenteeism is not dealt with harshly; many cities have no grievance procedure; drinking on the job is allowed; truck abuse by drivers is overlooked; accidents forgiven; featherbedding and loafing tolerated. A normal 8-hour workday with one hour of nonproductive time quickly can degenerate into a 4 or 5 hour workday. In essence, workers will do no more than they are required to do. If administrators and supervisors tolerate permissiveness in the maintenance garage, onroute or at the landfill, then the solid waste system will be very costly to operate and may eventually break down.

For these reasons, management must develop and enforce rules and regulations regarding employee relations. A grievance procedure with several steps to dismissal is the recommended method. Common problems and courses of action practiced in some cities are automatic 3-day suspension for drinking on the job, grounding the driver for accidents at a reduced pay level until the accident is investigated, and dismissal of employees for several unexcused absences or instances of truck abuse. Many drivers have caused $5-$10,000 damage to a truck by trying to "clutch" it out of a hole in a landfill. No refuse system should tolerate this kind of truck abuse from drivers.

CONTRACT COLLECTION AND DISPOSAL

Management of any refuse system is difficult under the best of conditions, thus many U.S. cities are contracting with private firms for collection. Some of the large U.S. cities which have turned part of their collection service over to private firms are New Orleans, Oklahoma City, and Phoenix. Several hundred smaller cities have turned over the entire operation to private firms.

Common reasons given by these cities for contracting the service are: (1) no new capital for equipment, (2) labor problems are too difficult to resolve, (3) present management cannot implement the changes needed, and (4) private firms can do it at a lower cost. All of these statements are valid except the last one concerning cost. By definition, any city should be able to collect refuse at less cost because cities don't pay the same taxes and are non-profit. In reality, refuse collection-disposal in many U.S. cities is so poorly managed that private firms can often provide the service at 25-40% less cost because of their better management practices. In general, private contractors pay higher wages than do cities, but productivity per worker or per truck is usually double that of cities. Private firms tend to purchase only the best equipment and often depreciate it over 3 years. They dismiss employees who do not produce. Maintenance is considered to be of primary importance. Laborers are placed on an incentive system to get the job done quickly and thoroughly. In essence, private firms provide diligent management. However, some U.S. cities such as Pontiac and Flint, Michigan, St. Petersburg, Florida, and Springfield, Massachusetts, have municipal systems that are lower in cost than would be the service if it were done by private firms. Thus, the decision of whether to contract the refuse collection-disposal operation or do it with city equipment and employees should rest on the capability of the city to effectively manage and continually fund the system.

SUMMARY

Successful refuse management in developing nations requires that sound policies must be practiced on both the national and local level to achieve a dependable, cost-effective and environmentally healthy refuse collection and disposal system. A national refuse program should provide provincial and local governments with the technical, financial and regulatory impetus to meet health and operational objectives; while local decision-makers should match their community's needs with the most efficient collection, disposal, funding and overall management options available.

Two constraints are common to developing nations and will govern their waste management policies. First, many of these governments are not sufficiently affluent to afford a high level of collection service or capital-intensive disposal technologies. Second, 75 percent of their waste stream is organic and, therefore, equipment must be utilized which can best collect and dispose of this type of waste. Given these constraints, the least costly and most efficient means of waste collection and disposal appears to be mechanical, bulk bin collection and sanitary landfilling.

Mechanical, bulk bin collection simplifies management by requiring fewer trucks and workers than other, more expensive methods and it facilitates the collection of heavy, organic wastes. Selection of bin size, location, and quantity must be based on the community's daily waste volume and population density. Truck fleet size should be determined by thorough time-motion studies conducted by engineers, planners and transportation experts.

Vehicle maintenance is the primary management problem contributing to system failure. It cannot be too strongly stressed that collection equipment should be the most sturdy and dependable available and that, once bought, it should receive regular, periodic maintenance by quality labor.

Two other problems often exist in operation management and can lead to system breakdown--an insufficient "span of control" over vehicles and crews on-route, and management-level permissiveness regarding careless or lazy behavior by crew members. These can be resolved by increased supervision through radio-equipped trucks, foremen in trucks driving the service area and strict rule enforcement.

Sanitary landfilling is the least costly and most feasible waste disposal technology for most developing nations. The cost-effectiveness of landfilling can be maintained by erecting transfer stations once hauling waste directly to a landfill becomes a non-productive use of collection labor and vehicles. To encourage environmental health and aesthetics, sanitary landfill operators should prevent groundwater contamination, discourage scavenging, control insects and rodents, prevent open burning and frequently compact and cover the waste with dirt.

Some communities have chosen to contract out their waste collection and disposal services because private companies do the job at a lower cost. This

can be true when a city's waste management practices are less efficient than those of a private enterprise. However, if a community practices diligent management policies, municipal collection and disposal should be more cost efficient than private services.